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Hurricane Seedlings

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ABSTRACT

It is generally recognized that hurricane formation occurs within a pre-existing region of disturbed weather and the dynamical and thermodynamical processes responsible for the disturbed weather are of several different types depending upon the source of energy that feeds the system. Disturbances in which air motion results from cold air underriding and displacing warm air are known as "Baroclinic systems". These are common over subtropical portions of the oceans and are more frequent in the spring and fall. A more common system in the tropics is similar to a simple mechanic heat engine and is driven by the release of latent heat of condensation. Finally, other systems draw from both sources of energy.

In the past it has not always been possible to properly recognize nor to document the history of such disturbances over large expanses of the tropical Atlantic Ocean with conventional data. During the last four years, satellites have provided us an opportunity, for the first time, to accurately identify and follow these "hurricane seedlings".

On the average, approximately 100 "hurricane seedlings" occur each year during hurricane season which extends from June 1 to November 30. One of ten become named storms and one of four develop a closed wind center characteristic of a depression. This means that one of every three depressions intensify and become a named storm.

Over half of the "seedlings" originate over, or to the east of Africa, by a process that is not yet understood. Baroclinic disturbances account for less than 15% of the hurricanes.

Seedlings that form in the Atlantic not only play a prominent role in the development of Atlantic hurricanes but also initiate more than 50% of the east Pacific tropical storms.

INTRODUCTION

It is generally recognized that one of the requirements for hurricane genesis is the pre-existence of a disturbance. These hurricane seedlings spawn convection and if the convection becomes organized, local warning occurs and a tropical storm forms. However, the lack of observing facilities over large expanses of the tropics have prohibited documentation of many of these disturbances.

Tropical meteorologists have been interested in transitory perturbations since Dunn (1940) first observed moving isobaric centers over the Caribbean. We have also known for some time that many of these systems form over Africa. For example, Piersig (1944), and Eldridge (1957) tracked the progress of disturbance lines (lines of thunderstorms) over west Africa and Shove (1946) found these line squalls were generally accompanied by troughs in the upper easterlies that eventually moved into the Eastern Atlantic. Several attempts have been made to track systems across the Atlantic Ocean; but, for the most part, they have been unsuccessful because of data limitations.

The meteorological satellite offers the potential for documenting the history of seedling disturbances, if these disturbances can be recognized by cloud patterns as seen on satellite pictures. Considerable progress has been made in recent years in our ability to interpret satellite pictures. The distinguishing characteristics of the hurricane/typhoon cloud patterns became recognizable almost immediately after the launching of the first Tiros Weather Satellite in April 1961.

Later, we found the cloud systems associated with tropical depressions develop a well-defined vortical pattern when surface winds reach the range of 20 to 30 kts. Two primary characteristics distinguish these vortical cloud patterns. The first is a well-defined set of low-level curved cumulus bands that spiral inward approximately parallel with the low-level winds. The other characteristic is an extensive middle and high cloud overcast which is usually conspicuously present east and northeast of the center of the vortical system and which often has a "comma" shape. Outflow at the cirrus level is indicated by the structure of the overcast in high quality weather satellite pictures. These two characteristics are shown schematically in Figure 1. "Vortical clouds" permit us to locate the place where depressions form in spite of conventional data limitations, particularly over the tropical Atlantic between Africa and the Caribbean.

Even more significant was the discovery that tropical waves are generally associated with an "Inverted V" cloud pattern. Figure 2 is an attempt to show schematically several features of this pattern and Figure 3 shows the westward progression of a tropical wave in June of 1967.

In general, clouds associated with tropical waves assume a banded appearance. The bands are arranged in a pattern somewhat resembling a series of V's placed upside down; thus, the term Inverted V. Frequently the V's are considerably flattened or rounded. The number of bands, or V's, vary from case to case. Occasionally only part or half of the V's are present. When the pattern is well marked, one can find an axis that marks the apex of the V's and indicates the place where cloud bands change orientation. East of the axis, denoted by heavy dashed line in Figure 3, bands are orientated from northwest to southeast; whereas to the west of the axis, the bands are southwest to northeast.

The Inverted V pattern is best defined in the eastern and central Atlantic and becomes less distinct as the pattern moves westward. The pattern usually disappears either near or before reaching the Antille Islands. The Inter-tropical Convergence Zone (ITCZ) cloudiness may or may not be part of the pattern. In the example shown in Figure 3, the ITCZ cloud band was influenced by the westward moving tropical wave.

Tropical Systems

The discovery that tropical waves can be identified on satellite pictures permit us to document the history of westward moving perturbations and to attempt a seasonal count of tropical systems for the first time. The initial effort was in 1967, so we now have four years of tabulations; however, some procedural changes between 1967 and 1968 limit the homogeneous data sample to 3 years. The purpose of this note is to present a 3 year summary of tropical systems that developed during the hurricane season which extends from June 1 to November 30.

The basic philosophy undergirding this effort is to identify and follow the course of all synoptic scale disturbances in the wind and pressure fields. By synoptic scale we imply a time scale of several days and a horizontal scale of hundreds of miles. Where possible, inferences have been based entirely on wind and pressure data. For example, the tracks of systems in the Caribbean were determined almost exclusively by upper air data from the network of island stations. Over the tropical Atlantic where conventional data are nonexistent, satellite pictures provide the only useful information. By definition we have decided to call the systems "tropical waves" if the stratocumulus field north of the equatorial trough zone is organized into an "Inverted V" pattern eventhough the main convective activity may be in the intertropical convergence zone (ITCZ). By this we are suggesting that a relative vorticity center is located within the belt of tradewinds. If an enhanced area of convection persists along the equatorial trough for more than 48 hours and if the stratocumulus field is not influenced, the system is labled as an ITCZ disturbance implying a relative vorticity center within the equatorial trough. It is recognized that our treatment of ITCZ disturbances is one of the weaker points in this summary. Cold lows in the upper troposphere have not been treated explicitly. The stronger one whose influence extends downward to the lower troposphere have been counted indirectly as tropical waves.

Table 1 compares the totals in several categories for the years 1968, 1969 and 1970. One of the more significant points to be noted in this table is the nearly 20% reduction in the number of systems in 1970. This observation may not be entirely real. Over the tropical Atlantic, satellite pictures are the sole source of information. When a system is strong and the cloud patterns well organized, the trans-Atlantic crossing can be established with reliability. This is not true for the weaker systems where the cloud organization is poorly defined. It has been our policy to assume a system weakened over the Atlantic if the wind data at Dakar confirmed the passage of a system but cloud organization was not sufficient to verify an ocean crossing. When wind data in the Antilles revealed the passage of a wave that could not be traced back to Africa, it has been assumed the system developed over the Atlantic. This implies that years characterized by more intense perturbations may have fewer systems by our counting scheme.

The last column of Table 1 presents 3 year averages for each category. Approximately 100 tropical systems develop each hurricane season. Twenty-five percent of these disturbances strengthen and become depressions while about ten percent intensify into named storms. One of every three depressions becomes a named storm.

Figure 4 shows the percentage of tropical systems that formed in five different geographic areas during the hurricane season of 1968 through 1970. The percentages are based on a 3 year total of 297 systems. The most significant and rather dramatic result is that over half of the systems originate over or to the east of Africa. Carlson (1969) attempted to track African waves back to their point of origin by performing a daily analysis over west Africa during the summer of 1968. His analysis extended eastward to 20 E. longitude. He found that most of the waves moved into the area of analysis from the east, and concluded they probably form over the high lands of east Africa. This conclusion is in agreement with Thompson (1965) who states that moving perturbations play no part in the weather of east Africa.

Figure 5 presents 3 year statistics on the average annual number of systems that passed three key locations; Dakar, Africa and the islands of Barbados and San Andres. Note that approximately two-thirds of the African systems maintained their identity while crossing the Atlantic and nearly one-half could be followed all the way to the Eastern Pacific Ocean. On the average, 56 systems emerged from Africa, while 52 entered the Caribbean from the Atlantic and 39 transversed central America.

Atlantic Tropical Storms

Table 2 summarizes the type of tropical systems that were responsible for depressions and named storms over the Atlantic during the four period of 1967 through 1970. Before presenting these results, it is necessary to clarify terminology to avoid problems in semantics. The systems responsible for tropical cyclogenesis may be divided into one of two broad categories according to their main source of energy: (1) Those drawing primarily on latent heat and, (2) those feeding mainly on a baroclinic source of energy. It is not always possible to assign a particular system to one of these categories because often both sources of energy are active. Regardless of the nature of the initiating system, intensification to storm or hurricane strength is always accompanied by a dominance of latent heat and establishment of a warm core. Within this general framework, there are five main types of tropical systems that have a bearing on the hurricane problem. Systems relying mainly on latent heat include:

1. ITCZ disturbances in both the Atlantic and Caribbean.
2. Non-ITCZ disturbances resulting from enhanced regions of convection. These are typical of developments during the late spring and early fall in the western Caribbean.
3. Tropical waves (also listed in this group although their energy source is not clearly understood).

Baroclinic systems are generally of two main types:

1. Upper Cold Lows - occasionally an upper tropospheric Cold Low will intensify and extend its influence downward in the vertical to the surface where a low may form.
2. Lower Lows - the second group forms on weak baroclinic zones that, in general, were originally associated with fronts. This type of development is usually initiated by an approaching upper trough in the westerlies.

Eventhough the initial impulse feeds mainly on a baroclinic field, convection is generally triggered and if the convection becomes concentrated, the release of latent heat may quickly destroy the original baroclinic field, thus changing the nature of the system from cold to warm core. The baroclinic development sequence is not the most common method of generating a hurricane and accounts for only a relatively small number of tropical storms each year, mainly those forming over the subtropical Atlantic and, to a lesser extent, the Gulf of Mexico.

The most striking result in Table 2 shows that African systems account for approximately 50% of both the named storms and depressions. Baroclinic systems were responsible for about one-third of the depressions and one-fifth of the named storms. It is interesting and important to observe that about 40% of the depressions initiated by tropical disturbances or African systems intensified and became named storms, while only 20% of the baroclinic induced depression strengthened to gale force. This difference is not surprising, since the relatively cool environment of a baroclinic system tends to hinder the hurricane process.

Pacific Tropical Storms

The Pacific, west of Central America, is a fertile genetical region for tropical storms mainly because of the small vertical shear in the horizontal winds and of the persistent cyclonic vorticity and low level convergence associated with the intertropical convergence zone, Simpson et al (1969). Satellite pictures have shown that this region is the second most active tropical storm area in the world. While many tropical storms form within the envelope of favorable conditions in this region, many of the impulses that initiate cyclogenesis come from migratory Atlantic disturbances.

Table 3 summarizes the nature of the disturbances that initiated eastern Pacific storms during the period from 1968 through 1970. Nearly 75% of the storms are spawned by systems that originate east of Central America and almost 50% of these can be tracked back to Africa. A surprisingly small number of storms (25%) were initiated by ITCZ disturbances that originated in the Pacific. Thus, we see that African systems play a prominent role in the development of both Atlantic and east Pacific storms. This is a remarkable result and one that was not anticipated.

REFERENCES

Carlson, Toby N., "Some Remarks on African Disturbances and Their Progress Over the Tropical Atlantic," Monthly Weather Review, Vol. 97, No. 10, Oct. 1969, pp. 716 - 726.

Dunn, G. E., "Cyclogenesis in the Tropical Atlantic," Bulletin of the American Meteorological Society, Vol. 21, No. 6, June 1940, pp. 215 - 229.

Eldridge, R. H., "A Synoptic Study of West African Disturbance Lines," Quarterly Journal of the Royal Meteorological Society, Vol. 83, No. 357, July 1957, pp. 303 - 314.

Piersig, W., "The Cyclonic Disturbances of the Sub-Tropical Eastern North Atlantic," Bulletin of the American Meteorological Society, Vol. 25, No. 1, Jan. 1944, pp. 2 - 16.

Shove, D. J., "A Further Contribution to the Meteorology of Nigeria," Quarterly Journal of the Royal Meteorological Society, Vol. 72, No. 311, 1946, pp. 105 - 110.

Simpson, R. H., Frank, Neil, Shideler, David, and Johnson, H. M., "Atlantic Tropical Disturbances of 1968," Monthly Weather Review, Vol. 97, No. 3, Mar. 1969, pp. 240 - 255.

Thompson, B. W., The Climate of Africa, Oxford University Press, New York, 1965, 132 pp.

Table 1 - Comparison of the tropical systems that occurred during the hurricane seasons of 1968, 1969, and 1970.

	1968	1969	1970	3 yr. aver.
Total systems, all types	107	105	85	99
Dakar systems	57	58	54	56
Barbados systems	59	44	53	52
San Andres systems	28	43	45	39
Depressions	19	28	24	24
Named Storms	7	13	7	9

Table 2 - Summary of the systems that initiated Atlantic named storms and depressions during the years 1967 through 1970. The systems have been divided into two categories (tropical and baroclinic) depending on their primary source of energy.

Years	Tropical: African Systems	Tropical: Disturbances	Baroclinic: Upper Lows	Baroclinic: Lower Lows	Totals
			Named Storms		
1967	4	3	0	1	8
1968	2	3	1	1	7
1969	7	3	2	1	13
1970	4	2	1	0	7
Totals	17	11	4	3	35
			Depressions		
1967	15	5	4	5	29
1968	8	5	3	3	19
1969	11	8	3	6	28
1970	17	2	3	4	26
Totals	52	20	13	18	92

Table 3 - Summary of the systems that initiated East Pacific tropical storms.

Type of Initiating System	YEAR 1968	1969	1970	3 yr. Totals	%
African Waves	7	4 4	11 11	22 22	46%
Atlantic Waves	2	0	0	2	4
Caribbean Waves	0	3	2	5	11
Caribbean ITCZ Disturbance	5	1	0	6	13
Pacific ITCZ Disturbance	5	2	5	12	26
TOTALS	19	10	18	47	

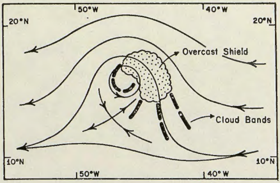

Figure 1 - Schematic of a tropical vortex cloud pattern.

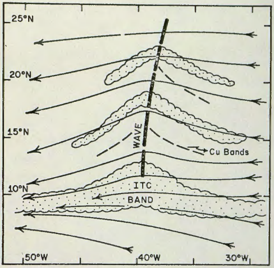

Figure 2 - A schematic showing the cloud pattern associated with a tropical wave.

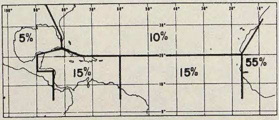

Figure 4 - Percentage of Atlantic tropical systems that formed in various geographical areas during the hurricane seasons of 1968, 1969 and 1970.

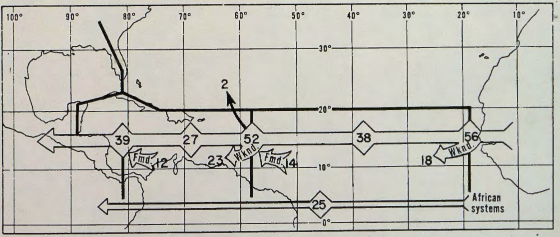

Figure 5 - A three year summary of the tropical systems observed from western Africa to the eastern Pacific during 1968 through 1970. The numerals indicate the average annual number of systems passing through different geographical regions.

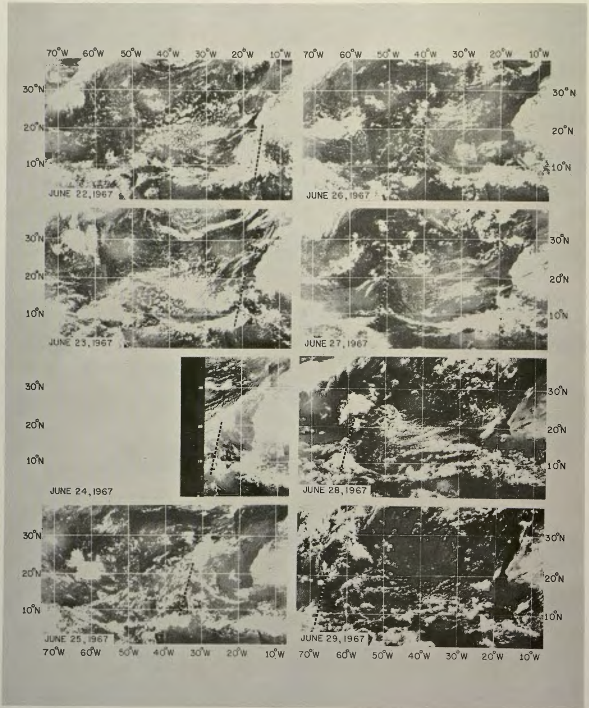

Figure 3 - A series of eight digitized cloud mosaics showing the history of a tropical wave that moved across the Atlantic.